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Agriculture and Food Development Authority

FINAL REPORT

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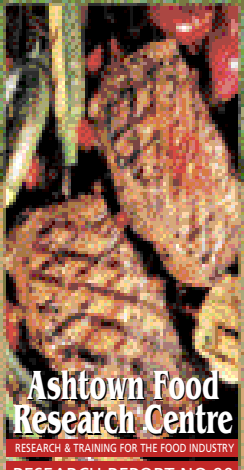
Enhancing the Healthiness, Shelf-life and Flavour of Irish Fresh Packaged Beef



Ashtown Food Research Centre

RESEARCH & TRAINING FOR THE FOOD INDUSTRY

RESEARCH REPORT NO 90

ENHANCING THE HEALTHINESS, SHELF-LIFE AND FLAVOUR OF IRISH FRESH PACKAGED BEEF

Editor-in-Chief: Dr Gerard Downey

Authors:

Aidan Moloney BSc PhD
Brendan Murray BSc PhD
Declan Troy MSc
Ashtown Food Research Centre, Teagasc, Ashtown, Dublin 15

Michael O'Grady BSc PhD
Joseph Kerry BSc PhD
Department of Food and Nutritional Sciences, University College, Cork.

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SUMMARY

Consumer concern about the nutritional aspects of health has heightened interest in developing methods for manipulation of the fatty acid composition of ruminant products. Ruminant meats such as beef and lamb are often criticised by nutritionists for having high amounts of saturated (S) fatty acids and low levels of polyunsaturated (P) fatty acids. The P:S ratio in beef is approximately 0.1, the ideal being about 0.4. However, an excessive increase in P concentration could predispose beef lipids to rancidity and loss of shelf-life. Moreover, the colour of meat is an important influence on the purchase decision of the consumer. This report summarises the Teagasc contribution to a larger project supported under the Food Institutional Research Measure programme administrated by the Department of Agriculture and Food. The Teagasc contribution focussed on enhancing the fatty acid composition of beef by nutritional manipulation of cattle using grazing and plant oils, the use of healthy - fatty acid enriched bovine tissue to make a processed beef product and the efficacy of dietary inclusion of tea catechins and rosemary to enhance the shelf-life of beef.

At Grange Beef Research Centre, grazing cattle were offered supplements containing sunflower oil or linseed oil for 5 months before slaughter. It was found that supplementing the diet of grazing animals resulted in a further beneficial effect on the fatty acid composition of muscle compared to grazing alone and that, while sunflower oil was more effective than linseed oil in increasing the concentration of conjugated linoleic acid, it had a more negative effect on the n-6:n-3 P ratio. With regard to shelf-life, while linseed oil supplementation caused a transient increase in lipid oxidation, this was not reflected in a loss in beef colour stability.

The fatty acid composition of muscle from cattle fed these different diets was measured before and after cooking and it was found that cooking had little effect on the fatty acid composition of beef. To capture additional value from supplementation of grazing cattle, beefburgers were produced that

were enriched with "natural" conjugated linoleic acid. These had similar sensory characteristics to regular beefburgers. At Grange Beef Research Centre, cattle were offered rations fortified with either rosemary or tea catechins. Neither antioxidant affected lipid oxidation or colour stability of beef.

INTRODUCTION

The relationships between dietary fat and the incidence of lifestyle diseases, particularly coronary heart disease, are well-established. Consequently, it has been suggested that the contribution of total fat and saturated fatty acids (S) to dietary energy intake should not exceed 35% and 10% of total intake respectively, the polyunsaturated fatty acids P : S ratio should be around 0.45 and the omega (n-) 6 to omega (n-) 3 P ratio should be less than 4 (Department of Health, 1994). Although it is the fat content and fatty acid composition of the whole diet which is important, research has focused on changing individual foods to be more in line with these guidelines.

Ruminant meats are often criticised by nutritionists for having high amounts of S and low P which is reflected in a low P:S ratio (approximately 0.1). In contrast, the ratio of n-6:n-3 P is beneficially low, approximately 2.0. This reflects the considerable amounts of n-3 P in beef, particularly α-linolenic (18:3n-3) and the long chain P, eicosapentaenoic acid (20:5n-3) and docosahexaenoic acid (22:6n-3). Meat, fish, fish oils and eggs are the only significant sources of n-3 P for man. Although meat has a lower concentration of these fatty acids compared to oily fish, it is a very significant source for many people since fish consumption may be low (British Nutrition Foundation, 1999). Ruminants also produce conjugated linoleic acid (CLA) which offers a range of nutritional benefits (Pariza *et al.*, 2001). Identification of strategies to increase the concentration of CLA and to decrease further the ratio of n-6: n-3 P would enhance the image of Irish beef as a healthier food compared to that from competing producers.

Manipulation of ruminant ration composition is one strategy that can be used for this purpose. Compared with conventional indoor rations, consumption of grass, rich in n-3 P, improves the fatty acid profile of beef by increasing P and CLA concentrations, decreasing the n-6:n-3 P ratio and decreasing the S concentration (French *et al.*, 2000). Enrichment of concentrate rations with plant oils, such as linseed oil or sunflower oil, also resulted in an increase in the concentration of CLA in bovine muscle (Noci *et al.*, 2005). No information is available on the efficacy of such supplementation strategies for grazing beef cattle.

For the consumer, the fatty acid composition of cooked meat is the most important issue while for the producer and processor, conversion of waste tissue, enriched with CLA, into higher value processed meats would greatly assist the sustainability of healthy beef production systems.

Appearance, specifically colour, is an important quality attribute influencing the consumer's decision to purchase. Increasing the P concentration *per se* and/or increasing the concentration of longer carbon-chain P, predisposes lipids to oxidation which is believed to be linked to muscle pigment oxidation and consequently to colour stability (O'Grady *et al.*, 1998). Strategies that improve the fatty acid composition must not impair other quality characteristics of beef and must be evaluated in this regard. Concerns regarding the safety and toxicity of synthetic antioxidants have resulted in much research in the area of natural antioxidants derived from plant sources. Tea catechins (TC) are a major group of polyphenolic flavonoids found in green tea. Rosemary (*Rosmarinus officinalis* L.) extracts (RE) contain antioxidant compounds, the most active being phenolic diterpenes such as carnosol, carnosic acid, rosmanol, epirosmanol, isorosmanol, methyl carnosate and other phenolic acids such as rosmarinic acid. Both these groups of "natural" antioxidants have been shown to increase beef shelf-life when added at the processing stage (Tang *et al.*, 2001a; Djenane *et al.*, 2002) but no information is available on the efficacy of dietary inclusion of these materials.

This work is part of a larger project funded by the Food Institutional Research Measure (FIRM) of the Department of Agriculture and Food. The main body of this report concentrates on the work carried out by Teagasc but for completeness and to increase the value of the report, data generated by our UCC collaborators is included where appropriate.

EXPERIMENT 1
THE COMPOSITION AND OXIDATIVE STABILITY OF LIPIDS IN *LONGISSIMUS* MUSCLE FROM GRAZING CATTLE SUPPLEMENTED WITH SUNFLOWER OIL OR LINSEED OIL

The first objective of this study was to investigate the effect of plant oil supplementation of grazing cattle on muscle fatty acid profile, in particular the n-3 and CLA concentrations. The second objective was to determine the effect of alterations in the fatty acid composition on colour and lipid stability of beef.

Materials and Methods

Forty-five Charolais cross-bred heifers (mean initial bodyweight = 330 kg, s.d. 39.90) were assigned to one of three dietary treatments (n = 15): unsupplemented grazing (GO); restricted grazing plus 2 kg/head/day of linseed oil-enriched meal (LO) or restricted grazing plus 2 kg/head/day of sunflower oil-enriched meal (SO). Concentrate and grass allowances were monitored at three-week intervals during a 5-month experimental period to achieve similar carcass weights across the treatments. Animals were slaughtered at a commercial facility, carcasses were chilled for 48h at 4°C and the *M. Longissimus dorsi* (LD) was excised from each carcass. Intramuscular fat was extracted from muscle samples using chloroform and methanol (2:1 v/v), methylated at 50°C for 20 minutes in alkaline and then acidic conditions and the fatty acid methyl esters obtained were analysed by gas chromatography. Vitamin E concentrations and proximate composition were measured as described by Dunne *et al.* (2005).

Samples of LD collected 48h post-mortem were vacuum-packed and stored at 4°C for a further 24h prior to analysis. Samples were cut into steaks (25.4 mm thickness) and placed in retail display trays. Trays were over-wrapped with oxygen permeable film for aerobic storage or flushed with 80% O_2: 20% CO_2 for storage under modified atmosphere conditions. All samples were stored for up to 10 days at 4°C under simulated retail display conditions (616 lux fluorescent lighting). Muscle colour was measured at 2 day intervals using an r-300 Chroma Meter (Minolta Co. Ltd., Japan) and reported as the 'a' redness value. Lipid oxidation was measured by distillation and results were expressed as 2-thiobarbituric acid reactive substances (TBARS) in mg malondialdehyde/kg muscle.

Results

Fatty acid data are summarised in Table 1. In general, the fatty acid composition of GO-fed cattle was similar to that previously reported. Compared to GO, SO-fed cattle had a higher concentration of C18:1 *trans*-11, C18:2, *cis*-9, *trans*-11 CLA, total P and n-6 P but a lower concentration of C12:0, C18:3 and C22:5 and higher P:S and n-6:n-3 P ratios. Compared to GO, LO-fed cattle had a higher concentration of C18:1 *trans*-11, *cis*-9, *trans*-11 CLA and n-6:n-3 P ratio but a lower concentration of C12:0, C20:4, C22:5 and C22:6. Compared to LO, SO-fed cattle had a higher concentration of C18:1 *trans*-11, C18:2, *cis*-9, *trans*-11 CLA, C20:4, C22:6 and n-6 P, a lower concentration of C18:3 and a higher n-6:n-3 P ratio.

Vitamin E concentration was lowest in LO-fed cattle and highest in SO-fed cattle (Table 1). Since similar amounts were supplied by the concentrates, this suggests greater metabolism and a possible greater requirement for vitamin E in the diet that supplied the greatest amount of n-3. There was no effect of diet on colour stability of beef (Table 2). Muscle lipids tended to be more susceptible to oxidation under modified atmosphere conditions (higher TBARS) than in aerobic packaging with muscle from SO-fed animals more stable than LO-fed animals (Table 2). Muscles from LO-fed animals had lower lipid stability compared to GO-fed animals on day 2 and 6 of display in modified atmosphere conditions.

Table 1: Fatty acid and Vitamin E concentrations in *M. Longissimus dorsi* from grazing cattle, either unsupplemented (GO) or supplemented with sunflower oil (SO) or linseed oil (LO)

Fatty acids (mg/100 g muscle)	GO	SO	LO	Sed[1]	Significance[2]
C12:0	1.52^{b}	0.88^{a}	0.88^{a}	0.157	***
C14:0	53.36	47.77	49.81	6.926	NS
C16:0	542.2	520.1	525.6	69.23	NS
C18:0	435.6	431.6	406.1	56.45	NS
C18:1 *cis*-9	843.0	847.1	780.1	125.3	NS
C18:1 *trans*-11	76.63^{a}	227.0^{c}	157.8^{b}	24.60	***
C18:2n6	58.80^{a}	78.39^{b}	62.50^{a}	4.816	***
CLA c9,t11	18.37^{a}	47.43^{c}	32.00^{b}	5.976	***
CLA t10, c12	1.73	0.93	1.51	0.479	NS
C18:3n3	34.34^{b}	22.14^{a}	31.72^{b}	2.929	***
C20:4n6	11.75^{a}	12.47^{a}	9.57^{b}	0.803	***
C20:5n3	7.63	6.40	6.40	0.561	0.06
C22:5n3	12.69^{b}	10.40^{a}	9.69^{a}	0.688	***
C22:6n3	2.71^{b}	2.34^{b}	1.65^{a}	0.269	**
SFA[3]	1089	1058	1037	134.5	NS
MUFA[3]	1032	1186	1037	143.3	NS
PUFA[3]	158.0^{a}	203.0^{b}	181.1^{ab}	14.93	*
PUFA:SFA	0.15^{a}	0.21^{b}	0.18^{ab}	0.015	**
n-6 PUFA[3]	86.92^{a}	106.5^{b}	92.51^{a}	6.405	***
n-3 PUFA[3]	59.49	48.18	55.03	4.725	0.07
n-6:n-3 PUFA	1.46^{a}	2.24^{c}	1.72^{b}	0.096	***
Total fatty acids	2513	2688	2513	329.1	NS
Vitamin E (ug/g)	2.70^{a}	3.16^{b}	1.99^{c}	0.224	**

[1]sed = standard error of the difference; [2]NS=not significant; *,** and *** = P<0.05, P<0.01 and P<0.001, respectively; within a row, means that differ significantly have a different superscript; [3]SFA = total saturated fatty acids; MUFA = total monounsaturated fatty acids; PUFA = total polyunsaturated fatty acids; n-6 PUFA = sum of C18:2, C18:3n-6, C20:2, C20:3n-6, C20:4 and C22:2; n-3 PUFA = sum of C18:3n-3, C20:3n-3, C20:5, C22:5 and C22:6.

Table 2: Surface redness ('a' value) and lipid oxidation (TBARS) in *M. longissimus dorsi* from grazing cattle either unsupplemented (GO) or supplemented with sunflower oil (SO) or linseed oil (LO) stored in aerobic or in modified atmosphere packs.

		Storage Time (days)					
	Packaging	0	2	4	6	8	10
Redness							
GO	Aerobic	17.99	13.46	9.36	8.10	8.83	8.74
SO	Aerobic	17.79	12.78	10.11	8.63	9.15	9.13
LO	Aerobic	18.53	13.23	9.87	7.61	7.97	8.79
sed[1]		1.067	0.900	0.639	0.528	0.551	0.607
Significance[2]		NS	NS	NS	NS	NS	NS
GO	MA[3]	17.99	17.33	14.84	13.03	10.20	9.09
SO	MA	17.79	17.45	15.41	12.56	10.63	8.52
LO	MA	18.53	18.30	16.56	14.60	10.81	9.50
sed[1]		1.067	0.703	0.960	1.351	0.973	1.004
Significance[2]		NS	NS	NS	NS	NS	NS
Lipid oxidation							
GO	Aerobic	0.83	0.82	0.46^{b}	0.39^{a}	0.65^{b}	0.86^{b}
SO	Aerobic	0.37	0.37	0.26^{a}	0.28^{a}	0.31^{a}	0.41^{a}
LO	Aerobic	0.52	0.67	0.27^{a}	0.62^{b}	0.63^{b}	1.01^{b}
sed[1]		0.200	0.258	0.088	0.065	0.135	0.169
Significance[2]		NS	NS	*	**	*	**
GO	MA	0.83	0.77^{a}	1.27^{b}	0.97^{a}	3.14	4.83^{b}
SO	MA	0.37	0.58^{a}	0.53^{a}	0.80^{a}	2.37	3.05^{a}
LO	MA	0.52	1.16^{b}	0.93^{b}	1.82	3.48	4.82^{b}
sed[1]		0.200	0.122	0.215	0.430	0.571	0.654
Significance[2]		NS	**	**	*	NS	*

[1]sed = standard error of the difference; [2]NS = not significant, * and ** = $P<0.05$ and $P<0.01$, respectively. Within packaging type and day, means with a common superscript do not differ significantly; [3]MA = modified atmosphere

Supplementing grazing animals with plant oil-enriched concentrates resulted in a further beneficial effect on the fatty acid composition of muscle compared to grazing alone. Sunflower oil was more effective than linseed oil in increasing the concentration of CLA and TVA but had a negative effect on the n-6:n-3 P ratio. While linseed oil had a less pronounced effect on the CLA concentration than sunflower oil, it also had a less negative effect on the n-6:n-3 P ratio. While linseed oil supplementation caused a transient increase in lipid oxidation, this was not reflected in a decline in colour stability.

EXPERIMENT 2
THE EFFECT OF COOKING ON THE FATTY ACID COMPOSITION OF BEEF

Most reports on enhancement of "healthy" fatty acids in beef relate to measurements on fresh tissue. Of greater relevance to the consumer is the quantity and quality of those fatty acids that remain after storage, display during sale, and cooking. Of these potential impacts on "healthy" fatty acids content, cooking has the most extreme effect on the tissue. Since little information is available on the effects of cooking on the concentration in beef of CLA in particular, an experiment was carried on *longissimus* muscle from the cattle described in experiment 1 that were fed different rations before slaughter.

Materials and Methods

Steaks were removed from frozen storage and allowed to thaw in circulating water at 12°C for 45 min. They were cut into cubes of approximately $3cm^3$ and blended in a Robot Coupe Blender (R301 Ultra, Robot coupe SA, France). Fifty grams of the blended samples was placed inside a glass bottle wrapped with aluminium foil and cooked in an oven maintained at 140°C for 30 min. Once cooked, lipid was extracted and fatty acids analysed by gas chromatography as described in Experiment 1.

Results and Discussion

There was no change in the fatty acid composition of LD, expressed as a percentage of total fatty acids or concentration, due to cooking (Table 3). It appears that the matrix of the muscle itself serves as a protective environment in which losses of fatty acids are minimised when the LD is cooked. In this study, lean muscle was used in which excess fat was trimmed from the muscle prior to cooking. If the fat on the side of a steak was subjected to grilling there would be a reduction in the total content of fatty acids in the steak as a whole. These findings are most positive from a consumer perspective, but the effects of other cooking methods merit investigation.

EXPERIMENT 3
MANUFACTURE OF BEEFBURGERS FROM CONJUGATED LINOLEIC ACID-ENRICHED BOVINE TISSUE

Dietary strategies that successfully enhance the fatty acid composition of beef muscle may also enhance the fatty acid composition of adipose tissue. This adipose tissue therefore would have potential value as a healthy food ingredient and in particular as a natural source of CLA. The use of this ingredient in processed meat products would also enhance the sustainability of a high CLA – beef production system. The objective of this study was to demonstrate the utility of fat as a functional ingredient enriched in CLA for the production of a processed beef product using a beefburger as a model.

Materials and Methods

Initially, adipose tissue was evaluated for its content of beneficial fatty acids as described for experiment 1. For each animal diet, beefburgers (formulated to contain 20% fat) were then produced from the *M. semimembranosus* and the CLA-enriched-fat. Fatty acid analysis was carried out on the burgers as described for experiment 1. An in-house, trained panel of 20 people from different backgrounds was established to assess the following sensory attributes of the burgers: texture (hardness, softness), juiciness and flavour quality using the procedures of the American Meat Science Association (AMSA, 1995). In

Table 3: Fatty acid composition of uncooked and cooked *M. longissimus dorsi* from grazing cattle, either unsupplemented (GO) or supplemented with sunflower oil (SO) or linseed oil (LO)

Fatty acid (g/100g fatty acids)	GO	SO	LO
C12:0			
raw	0.98 ± 0.29	0.80 ± 0.20	0.89 ± 0.20
cooked	1.02 ± 0.27	0.84 ± 0.27	0.91 ± 0.23
Significance	NS	NS	NS
C14:0			
raw	28.29 ± 5.68	25.84 ± 5.17	28.93 ± 5.47
cooked	29.06 ± 5.65	25.50 ± 4.75	29.48 ± 5.97
Significance	NS	NS	NS
C16:0			
raw	228.3 ± 14.7	213.9 ± 16.6	230.9 ± 16.6
cooked	233.7 ± 14.8	216.2 ± 15.6	234.0 ± 16.9
Significance	NS	NS	NS
C18:0			
raw	134.1 ± 12.6	133.2 ± 18.9	137.1 ± 16.7
cooked	133.0 ± 11.3	130.1 ± 17.5	135.0 ± 16.5
Significance	NS	NS	NS
C18:1 trans 11			
raw	23.12 ± 6.81	69.99 ± 15.55	52.39 ± 6.70
cooked	22.26 ± 5.90	63.90 ± 14.06	49.89 ± 5.64
Significance	NS	NS	NS
C18:1 cis - 9			
raw	322.9 ± 27.6	289.5 ± 21.6	284.4 ± 32.8
cooked	320.6 ± 31.8	285.1 ± 23.3	280.7 ± 33.8
Significance	NS	NS	NS
C18:2 n6 cis			
raw	31.96 ± 10.75	45.44 ± 7.93	38.06 ± 15.12
cooked	33.86 ± 12.14	49.32 ± 13.14	39.10 ± 17.62
Significance	NS	NS	NS

Table 3 (contd.): Fatty acid composition of uncooked and cooked *M. longissimus dorsi* from grazing cattle, either unsupplemented (GO) or supplemented with sunflower oil (SO) or linseed oil (LO)

Fatty acid (g/100g fatty acids)	GO	SO	LO
C18:3 n3			
raw	17.22 ± 5.30	10.87 ± 2.09	17.94 ± 9.53
cooked	18.00 ± 5.75	11.57 ± 3.19	18.26 ± 10.54
Significance	NS	NS	NS
CLA c9, t11			
raw	7.03 ± 2.45	13.60 ± 2.14	9.23 ± 1.72
cooked	7.04 ± 2.58	13.27 ± 2.26	9.44 ± 1.87
Significance	NS	NS	NS
CLA all trans			
raw	0.89 ± 0.22	3.33 ± 1.08	2.78 ± 0.85
cooked	0.73 ± 0.23	2.71 ± 1.07	2.30 ± 0.89
Significance	NS	NS	NS
C20:4 n6			
raw	12.92 ± 4.86	13.45 ± 2.40	11.45 ± 4.12
cooked	13.48 ± 4.97	13.89 ± 3.76	11.57 ± 4.88
Significance	NS	NS	NS
C20:5 n3			
raw	8.15 ± 4.34	5.95 ± 1.61	6.54 ± 3.68
cooked	8.55 ± 4.29	6.42 ± 2.74	6.62 ± 4.21
Significance	NS	NS	NS
C22:5 n3			
raw	10.00 ± 3.93	8.21 ± 1.64	7.98 ± 2.63
cooked	10.07 ± 3.37	8.51 ± 2.61	7.90 ± 2.82
Significance	NS	NS	NS
C22:6 n3			
raw	1.37 ± 0.66	1.06 ± 0.32	0.90 ± 0.42
cooked	1.37 ± 0.55	1.21 ± 0.51	0.88 ± 0.46
Significance	NS	NS	NS

Table 3 (contd.): Fatty acid composition of uncooked and cooked *M. longissimus dorsi* from grazing cattle, either unsupplemented (GO) or supplemented with sunflower oil (SO) or linseed oil (LO)

Fatty acid (g/100g fatty acids)	GO	SO	LO
SFA	*SFA2*		
raw	408.5 ± 27.2	388.5 ± 14.9	414.2 ± 17.9
cooked	413.7 ± 26.0	387.3 ± 17.8	415.9 ± 18.1
Significance	NS	NS	NS
MUFA2			
raw	422.9 ± 30.6	440.4 ± 20.8	412.9 ± 34.6
cooked	421.0 ± 35.3	431.3 ± 26.4	407.1 ± 38.8
Significance	NS	NS	NS
PUFA2			
raw	94.26 ± 29.19	107.6 ± 14.0	99.21 ± 34.75
cooked	97.91 ± 30.23	112.8 ± 24.2	100.4 ± 40.0a
Significance	NS	NS	NS
n-6 PUFA2			
raw	48.86 ± 16.81	63.56 ± 10.36	52.91 ± 19.88
cooked	51.41 ± 18.23	68.26 ± 17.38	54.08 ± 23.31
Significance	NS	NS	NS
n-3 PUFA2			
raw	36.74 ± 13.89	26.09 ± 5.37	33.36 ± 15.77
cooked	37.99 ± 13.54	27.70 ± 8.63	33.67 ± 17.69
Significance	NS	NS	NS
P:S ratio			
raw	0.24 ± 0.09	0.28 ± 0.04	0.24 ± 0.10
cooked	0.24 ± 0.08	0.29 ± 0.07	0.24 ± 0.11
Significance	NS	NS	NS
n-6:n-3 Ratio			
raw	1.35 ± 0.23	2.48 ± 0.37	1.66 ± 0.33
cooked	1.36 ± 0.24	2.53 ± 0.36	1.68 ± 0.33
Significance	NS	NS	NS

[1]NS: not significant; [2]As defined in Table 1

addition they were also asked to give an overall acceptability score for the various samples. Samples were graded on a categorical scale from 1 to 6, in which 1 is generally least favoured and 6 the most preferred.

Results and Discussion

Subcutaneous adipose tissue fatty acid composition is summarised in Table 4 while that of the beefburgers is summarised in Table 5. In general, adipose tissue was characterised by a higher proportion of CLA and a lower proportion of long-chain fatty acids than muscle (Table 1). The burger fatty acid composition reflected the fatty acid composition of adipose tissue more than muscle. In general, high preference scores were associated with the pasture and oil-supplemented diets with little difference between treatments indicating that there was no detrimental effect on burger flavour and other sensory qualities. Thus, though the quality of the lipids has been improved (incorporation of CLA and other unsaturated fatty acids such as C18:3 n3), it was not at the expense of important sensory attributes.

EXPERIMENT 4
THE QUALITY OF BEEF FROM CATTLE SUPPLEMENTED WITH TEA CATECHINS AND ROSEMARY EXTRACT

Previous studies have reported that direct addition of tea catechins (TC) improved the oxidative stability of raw and cooked beef, poultry, pork and fish (Tang *et al.*, 2001a). While supplementation of poultry diets with TC resulted in reduced levels of lipid oxidation in chicken meat (Tang *et al.*, 2001b), no studies have been carried out to examine the potential antioxidant efficacy of TC added to bovine diets. Beneficial antioxidant effects of rosemary extract (RE) or oleoresin as a result of direct addition, have been extensively studied and reported in a variety of meat types including beef, beef products, pork, pork products, turkey and goat meat products (Djenane *et al.*, 2002). The aim of the current study was to investigate the effects of dietary TC and RE supplementation of beef animal diets on the oxidative stability of fresh beef. The antioxidant potential of TC and RE, supplemented in the animal diets, was determined by direct addition of both antioxidants to minced beef.

Table 4: Fatty acid concentration in subcutaneous adipose tissue from grazing cattle either unsupplemented (GO) or supplemented with linseed oil (LO) or sunflower oil (SO)

Fatty acids (mg/g tissue)	GO	SO	LO	sed[1]	Significance[2]
C12:0	0.35^{b}	0.21^{a}	0.23^{a}	0.031	***
C14:0	15.98^{b}	12.27^{a}	13.72^{a}	1.036	**
C14:1	5.44	5.64	4.91	0.631	NS
C15:0	3.92^{b}	2.59^{a}	2.95^{a}	0.187	***
C16:0	132.9^{b}	106.9^{a}	112.2^{a}	5.699	***
C16:1	26.86	24.64	21.68	2.076	0.06
C17:0	6.78c	4.90^{a}	5.70^{b}	0.393	***
C17:1	5.63^{b}	4.58^{a}	4.39^{a}	0.342	**
C18:0	83.67$_{b}$	65.69^{a}	71.74^{a}	6.331	*
C18:1*cis*-9	226.9	218.8	203.4	11.66	NS
C18:1*trans*-11	25.67^{a}	59.54^{c}	46.02^{b}	3.888	***
C18:2n6 *cis*	6.60^{a}	8.92^{c}	7.52^{b}	0.612	**
CLA c9,t11	10.23a	24.23^{c}	16.72^{b}	1.540	***
CLA t10,c12	0.78^{b}	0.15^{a}	0.17^{a}	0.072	***
C18:3n3	5.44^{b}	3.19^{a}	5.23^{b}	0.756	*
C20:0	0.80^{b}	0.65^{a}	0.79^{b}	0.041	**
C20:1	0.98	0.92	1.04	0.107	NS
C20:2n6	0.73^{a}	0.73^{a}	1.98^{b}	0.110	***
C20:4n6	0.26	0.27	0.22	0.023	NS
C20:5n3	0.19^{a}	0.32^{b}	0.65^{c}	0.048	***
C22:5n3	0.64	0.49	0.59	0.073	NS
C22:6n3	0.05	0.03	0.04	0.009	NS
SFA[3]	244.8^{b}	193.6^{a}	207.7^{a}	10.83	***
MUFA[3]	303.5^{a}	337.6^{b}	299.0^{a}	16.03	*
PUFA[3]	28.32^{a}	40.13^{b}	35.55^{b}	2.387	***
PUFA:SFA	0.12^{a}	0.21^{c}	0.17^{b}	0.013	***
n-6 PUFA	10.72	11.62	12.01	0.810	NS
n-3 PUFA	6.59b	4.13^{a}	6.64^{b}	0.767	**
n-6:n-3 PUFA	1.63^{a}	2.81^{b}	1.81^{a}	0.134	***
Total fatty acids	622.4	625.2	618.4	27.79	NS

[1]sed = standard error of the difference;[2]NS = not significant; *, ** and *** $P<0.05$, $P<0.01$ and $P<0.001$, respectively; within a row, means that differed significantly have a different superscript; [3]As defined in Table 1

Table 5: Fatty acid composition of beefburgers (mg fatty acid / 100g burger) made from tissue from grazing cattle either unsupplemented (GO) or supplemented with linseed oil (LO) or sunflower oil (SO)

Fatty acid[a]	GO	SO	LO	Significance[1]
C12:0	38.4 (5.9)	32.6 (4.1)	32.6 (5.4)	*
C14:0	1135.2 (159.7)	1060.4 (128.8)	1066 (139.9)	*
C15:0	239 (33.6)	208.6 (24.2)	196.6 (26.2)	*
C16:0	6882.6 (965.3)	6334.2 (707.2)	6427.4 (810.3)	*
C16:1 *cis*-9	1358.4 (183.2)	1127 (108.4)	1040.8(133.9)	*
C17:0	305.8 (45.6)	272.2 (29.2)	267.8 (33.4)	*
C17:1	29.8 (4.8)	23 (2.9)	21.8 (4.2)	*
C18:0	3596.2 (594.4)	3684.6 (401.1)	3488 (432.6)	*
C18:1 *trans*-11	1051 (165.0)	2509.8 (263.3)	1941.6 (250.3)	***
C18:1 *cis*-9	8341 (1126.0)	8050 (778.0)	7482 (911.0)	***
C18:1 *cis*-11	286 (36.7)	263.4 (23.8)	256.2 (31.4)	*
C18:2 *n6 cis*	294.4 (41.3)	402.8 (35.9)	326.2 (37.2)	***
C18:3 *n3*	227.4 (31.3)	148.4 (14.8)	193 (27.1)	***
C20:0	23.6 (4.2)	26 (3.2)	22.8 (2.4)	*
CLA *cis*-9, *trans*-11	327.6 (47.4)	647 (59.3)	454 (61.3)	***
C18:3 c9, t11, c15	22.2 (2.17)	25.8 (2.9)	27.8 (2.2)	*
C20:4 *n6*	35.4 (4.3)	33.2 (1.6)	34.4 (3.4)	*
C20:5 *n3*	34.6 (9.8)	21.2 (6.8)	22.2 (4.9)	*
C22:5 *n3*	31.2 (3.5)	21.2 (0.8)	25.6 (3.4)	*

[a]Means are for 5 batches per diet (each sample analysed in duplicate).
[1]NS = not significant; *, ** and *** P<0.05, P<0.01 and P<0.001, respectively

Materials and Methods

Beef cattle diets were supplemented with TC (1000mg/animal/day) and RE (1000mg/animal/day) for 103 days preceding slaughter. Post-slaughter, the oxidative stability of *M. longissimus dorsi* (LD) steaks was evaluated as described in experiment 1.

Results and Discussion

Dietary supplementation with TC and RE did not increase LD α-tocopherol concentrations or pH. In LD steaks stored aerobically or in modified atmosphere packs (80% O_2:20% CO_2) (MAP) for up to 8 days at 4 °C surface redness and lipid stability were not significantly improved as a result of supplementation with TC and RE. Similarly, no improvement in the sensory properties and lipid stability of cooked LD slices stored aerobically or in 30% CO_2:70% N_2 for up to 11 days at 4°C was observed. Direct addition of TC (1000 ppm) and RE (1000 ppm) significantly (P<0.05) improved the colour and lipid stability in LD patties stored in 80% O_2:20% CO_2 for up to 8 days at 4 °C, thus demonstrating the antioxidant potential of TC and RE supplements employed in the present study. Possible reasons for the apparent lack of effect of dietary inclusion of TC or RE could be an insufficient level of inclusion in the diet, lack of absorption from the gastro-intestinal tract or degradation during intestinal and/or post-intestinal metabolism.

EXPERIMENT 5
DOSE-RESPONSE EFFECTS OF ENRICHING THE DIETS OF BEEF CATTLE WITH CATECHINS ON LIPID OXIDATION AND SHELF-LIFE OF FRESH BEEF

Supplementation of beef cattle diets with TC (1000 mg TC/animal/day for 103 days pre slaughter) did not significantly improve beef quality in terms of colour and lipid stability (experiment 4). It was suggested that the lack of an effect of dietary TC may be attributed to the level of TC included in the diet. The aim of this study was to assess the effect of increasing levels of TC on fresh beef quality.

Materials and Methods

Twenty eight continental cross-bred heifers were randomly assigned to one of four diets for 90 days pre-slaughter. The control group was offered a diet consisting of a barley-based concentrate and the three remaining groups were fed the control diet plus incremental amounts of TC as mg/animal/day (1000 (TC 1000), 4000 (TC 4000) and 10,000 (TC 10,000). The TC supplement (81.43%) extracted from green tea (*Camellia sinensis* L. variety *assamica*) was supplied by Kinglong Natural Plant Products Industry Ltd., China. Post-slaughter, *M. longissimus dorsi* (LD) samples were vacuum-packed and stored at 0°C (~ 1 week) prior to analysis. LD samples were cut into steaks (~ 25.4 mm thickness), placed in retail display trays and flushed with 80% O_2 : 20% CO_2 for storage in modified atmosphere packs for up to 8 days at 4°C under simulated retail display conditions (616 lux fluorescent lighting). Colour and lipid oxidation were measured as described in experiment 1.

Results and Discussion

Dietary supplementation with increasing concentrations of TC (1000, 4000 and 10,000 mg TC/animal/day) did not significantly improve the colour or lipid stability of LD steaks relative to controls (Table 6). The lack of a dietary effect of TC on fresh beef quality may have been due to degradation of TC in the alkaline conditions of the bovine rumen and intestine.

Table 6: Effect of dietary TC (0, 1000, 4000 and 10,000 mg/animal/day) on surface redness ('a' value) and lipid oxidation (TBARS) in *M. longissimus dorsi* (LD) stored in modified atmosphere packs (MAP) (80% O_2 :20% CO_2)

Treatment	Storage time at 4°C (d)									
	Surface redness ('a' value)					TBARS (mg MDA/kg)				
	0	2	4	6	8	0	2	4	6	8
Control	20.86[a]	18.03	17.17	15.31	12.68	0.07[a]	0.43	0.43	1.26	1.80
+ TC 1000	21.41	18.08	16.82	13.77	12.26	0.07	0.43	0.74	1.10	2.16
+ TC 4000	21.59	18.23	16.16	15.56	11.60	0.07	0.33	0.52	1.17	2.07
+ TC 10,000	21.67	18.07	15.96	14.44	12.09	0.07	0.35	0.65	1.35	2.14

[a]Within each day, no significant effects were observed for dietary treatment, $P > 0.05$.

CONCLUSIONS

- Supplementing grazing animals with plant oil-enriched concentrates resulted in a further beneficial effect on the fatty acid composition of muscle compared to grazing alone.
- Sunflower oil was more effective than linseed oil in increasing the concentration of CLA and trans vaccenic acid but had a negative effect on the n-6:n-3 P ratio.
- Compared to sunflower oil, linseed oil had a less negative effect on the n-6:n-3 P ratio.
- While linseed oil supplementation caused a transient increase in lipid oxidation, this was not reflected in a loss of colour stability of beef.
- Cooking had little effect on the fatty acid composition of beef.
- Beefburgers enriched with "natural" CLA had similar sensory characteristics to regular burgers.
- Dietary supplementation with rosemary or tea catechins did not affect lipid oxidation or colour stability of beef.

RECOMMENDATIONS TO INDUSTRY

The results of this project clearly indicate substantial increases in the CLA content of Irish beef and adipose tissue when animals are reared on fresh pasture and supplemented with plant oils, particularly oils rich in linoleic acid. There are clear increases in the content of C18:1 *trans* –11 which may be converted to CLA in human tissue. The increased levels of vitamin E also present in the beef and adipose tissue appear to reduce the production of flavour volatiles associated with off-flavours and reduced shelf-life; beefburgers produced from this meat and adipose tissue scored favourably in sensory evaluations.

- CLA and other beneficial fatty acids could facilitate the Irish beef industry in marketing its produce as being healthier, tastier and with longer shelf-life. In this way, Irish beef could satisfy the more-discerning European beef consumer and increase market share.

- Functional foods are defined as foods fortified with ingredients which are capable of having, or claim to have, a positive effect on health. Irish beef fortified with CLA may be one such food.

- The largest store of CLA is found in adipose tissue or the animal fat. This may potentially be used as a functional ingredient since it is involved in the manufacture of several products such as beefburgers, sausages etc.

- If a higher value of Irish beef is realised in Europe, it would increase the value of beef and allow a higher standard of living and better returns from beef farming.

- A further positive result was that, under the conditions of this study, beneficial fatty acids were preserved during cooking.

- In contrast, dietary inclusion of tea catechins or rosemary extract did not seem to be a viable alternative to the use of established anti-oxidants such as vitamin E.

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Ashtown Food Research Centre

RESEARCH & TRAINING FOR THE FOOD INDUSTRY

Ashtown, Dublin 15, Ireland.

Telephone: (+353 1) 805 9500

Fax: (+353 1) 805 9550